Dynamic Effects of Airborne Water Droplets on Air-Sea Interactions: Sea-Spray and Rain

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LONG-TERM GOALS

We anticipate that this research will lead to an improved understanding of water droplet mediated air-sea fluxes with implications in basic research, satellite or land-based remote sensing of the ocean surface, electromagnetic communication, military surveillance, and weather forecasting. We foresee that this work will become the initial stages of a long-term effort involving further development of theoretical work, and laboratory and field experiments.

OBJECTIVES

In recent years, small-scale surface dynamics (waves, turbulence, bubbles, and drops) have been recognized as crucial to global climate through their impact on air-sea fluxes. However, the dynamics of a turbulent surface can be quite complicated, and at times (at high wind speed) the main problem is to identify the surface which then resembles a mixture of bubbles and drops. While the upper ocean bubbly mixture has been relatively studied, especially in the context of the acoustics, it appears that airborne water droplets have been widely ignored despite their undeniable importance.

Recent work point toward the fact that airborne water droplets can exchange with the atmosphere a consequent amount of energy and enthalpy, especially at high wind speeds. At low wind speed, it appear that a significant fraction of shear stress can be carried by falling rain and transmitted to the wind field. The direction and amplitude of the momentum and enthalpy fluxes depend on the origin of the droplet (the upper atmosphere for the rain, the ocean surface for sea spray), and in the case of sea spray, if it evaporates entirely or falls back.

This project is aimed at improving and use an existing sea-spray Lagrangian turbulent transport and evaporation model to study the heat, moisture and momentum balances in the lower atmospheric boundary layer when water droplets are present.

APPROACH

We propose to improve our current sea-spray Lagrangian turbulent transport and evaporation model to include several important effects that have been neglected in the past. Also, we propose to generalize part of the parameterizations such that the model is adequate for a wide range of conditions and therefore usable to study both suspended sea-spray and also rain droplets. The numerical part of this

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14. ABSTRACT
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project will be aimed at further developing the model, and making use of a cluster of PC computers to run the calculations. In addition, a laboratory experimental part is proposed for the later years, in which we will examine the momentum exchanges between impacting rain and the ocean surface.

WORK COMPLETED

This project started in June 2005 and is therefore in its first few months. The initial part of project was dedicated to the purchase and implementation of a large a computer system to perform the model calculations. The computer system has been ordered and should be delivered shortly.It was decided that the system would consist of twenty-four, single processor PCs on which processing will be performed and a large server to distribute computing tasks and recombine the results. The server has been fabricated, tested and is operating properly. Concurrently, we are modifying the currently existing model to account for anisotropy in the Lagrangian turbulence in the air-flow above the wavy ocean surface, and include wave-turbulence interactions. Do date, we believe we have successfully implemented turbulence closures and the wave effects. We also have developed a general description of the Wind velocity profile above the wavy surface which includes the diffusive molecular layer. We are currently developing the equivalent algorithm to account for molecular layers in the profiles of temperature and humidity. We have also initiated some modifications for the code to be able to run on the new computer system

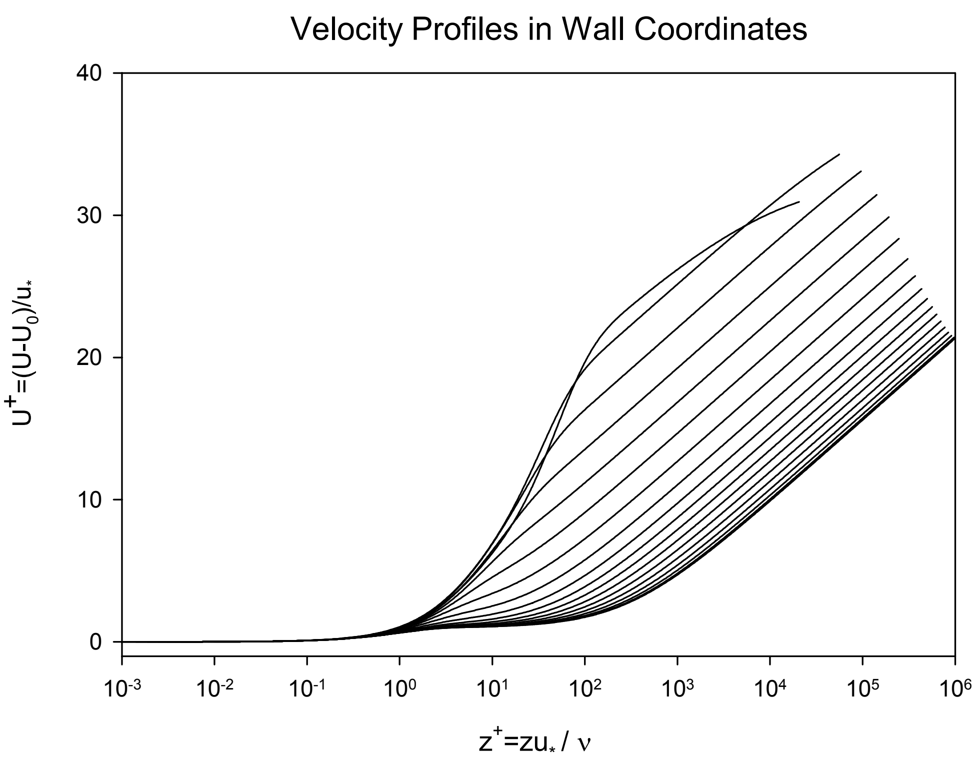

Figure 1. Wind profiles from 1m/s to 35m/s in 2m/s increment and plotted in wall layer coordinate. Note the presence of a well defined viscous sub-layer and the effect of stratification at low wind speed (the top most profiles).

RESULTS

We have developed a Spray Lagrangian Turbulent Transport and Evaporation model (hereafter SpLaTTE) which includes droplet microphysics, propagating surface waves, atmospheric stratification, turbulence, and the complete linear unsteady equation of motion for the droplets. Our preliminary results indicate that the short thermal and inertial response time of small droplets is such that they decelerate and warm up significantly as they approach the thermal and momentum boundary layer near the ocean surface. We have therefore spent considerable effort in developing a generalized form for the wind profiles (including stability), which account for the viscous layer close to the interface. Figure 1 shows the wind profile above the surface (plotted in wall layer coordinate) for wind speeds from 1 to 35m/s in increments of 2m/s. The departure from the log-layer at the lowest wind speed is due to effects of atmospheric stratification, effects that disappear at higher wind speeds. Another significant improvement to the model was the inclusion of fully non-isotropic Lagragian turbulence for the velocity, temperature and humidity variables. The turbulence includes wave-turbulence interaction. We believe we have successfully implemented the closures and wave effects. Finally, we have also improved upon several existing parameterizations and found that it is possible to retrieve air-sea drag coefficients that are consistent with recent observation at high wind speed by a modification of the Charnok coefficient (figure 2).

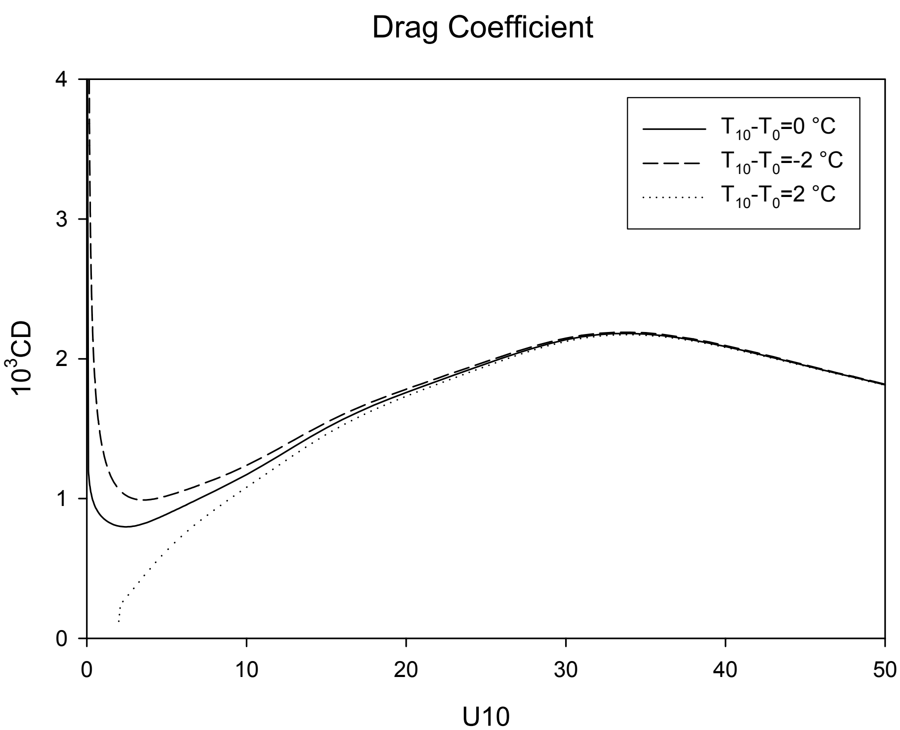

Figure 2. Drag coeffiecnt that results from the wind profiles shown as a function of wind speed and for stable (dot) unstable (dash) and neutral (solid) conditions.

IMPACT/APPLICATIONS

We anticipate that this research will lead to an improved understanding of water droplet mediated air-sea fluxes. Potential impacts are cited above and also include a better understanding of air-Sea fluxes, especially at high wind speeds when significant amount of water droplets can be suspended in the air-flow

RELATED PROJECTS

None